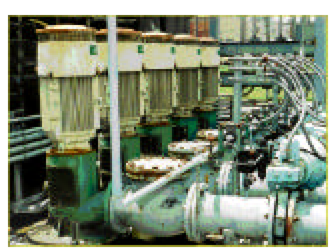
## Energy Savings with Pump Systems

- How important are pump systems?
- Some pump system theory
- Prescreen pump systems: the VITAL FEW and the trivial many
- Identifying energy savings opportunities



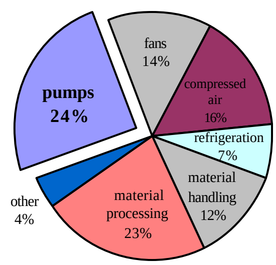
## Big Picture Perspectives: Industrial Motor Systems

- Industrial motor systems:
  - Are the *single largest electrical end use* category in the American economy
  - Account for 25% of U.S. electrical sales



# Industrial motor energy use by application

**Total 2.3 Quadrillion Btu/yr**




Source: United States Industrial Electric Motor Systems Market Opportunities Assessment, Office of Industrial Technologies, Office of Energy Efficiency and Renewable energy, US DOE, December 1998, Table 1-16, page 43





# Important fundamental relationship

$$\textbf{Fluid power} = \frac{\textbf{Flow rate (gpm) x Head (ft) x specific gravity}}{3960}\ \textbf{(hp)}$$

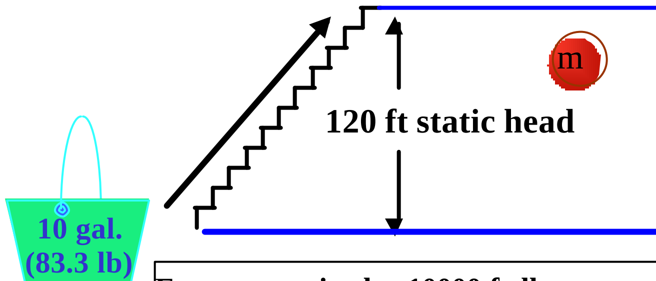
**AND**

**Fluid energy = Fluid power x operating time**

**Reduce the run time**
**Reduce the flow rate**
**Reduce the head**

} **Reduce energy use, cost**

Ideally, fluid movement energy requirements are proportional to mass and head

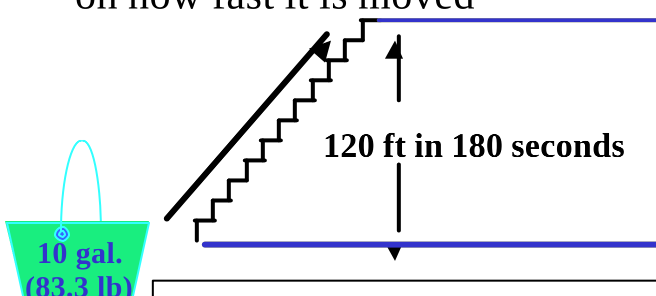



**Energy required = 10000 ft-lb, or**
**3.24 kcalories**
**(less than one M&M)**





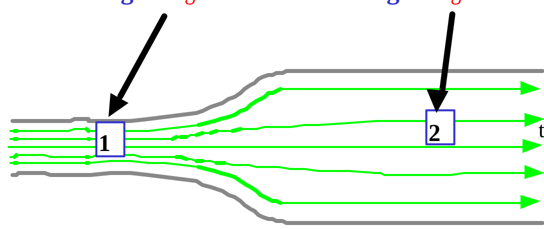
Ideal <u>power</u> depends
on how fast it is moved




**Power required = 0.1 horsepower, or**
**65 kcalories per hour**

# The Bernoulli equation is slightly modified to account for friction:

$$\left(\frac{V_1^2}{2g} + \frac{P_1}{g} + Z_1\right) = \left(\frac{V_2^2}{2g} + \frac{P_2}{g} + Z_2\right) + H_f$$




Hydraulic energy at point 2 is lower than at point 1 because of the friction loss, so we balance the equation by adding it here



# **Pipe** friction loss estimates are usually based on an equation referred to as Darcy-Weisbach

This equation is very useful to understand what parameters influence *frictional* losses in piping:

$$\boxed{H_f = f \cdot \frac{L}{d} \cdot \frac{V^2}{2g}}$$

$H_f$ = pressure drop due to friction (ft)
f = Darcy friction factor
L = pipe length (ft)
d = pipe diameter (ft)
$\frac{V^2}{2g}$ = velocity head (ft)

## **Component** friction losses are primarily dependent on experimental data

For pipe components, frictional losses have generally been estimated based on the velocity head.

$$H_f = K \bullet \frac{V^2}{2g}$$

$K$ = Loss coefficient

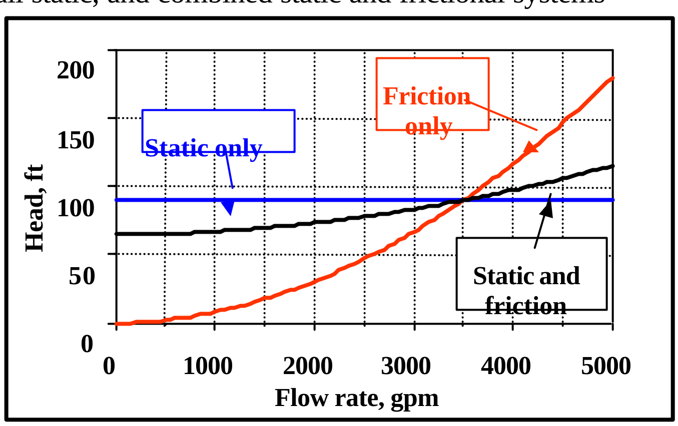
$\frac{V^2}{2g}$ = velocity head

K is a function of size, and for valves, the valve type, and valve % open.

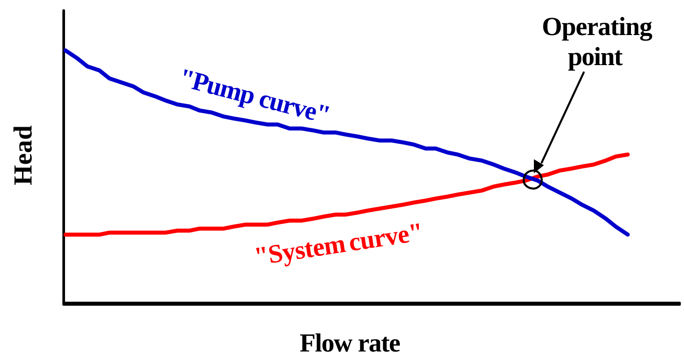




System head curves for all frictional,
all static, and combined static and frictional systems



The system operating point is at the intersection of the pump and system head-capacity curves





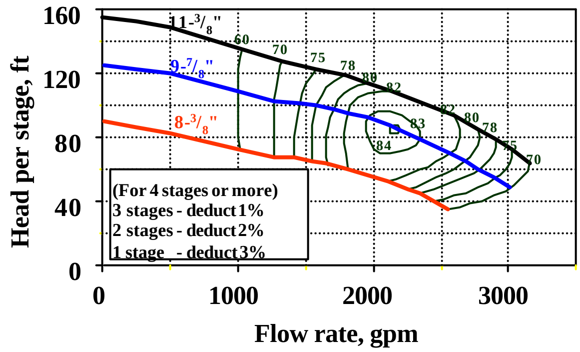



Pump affinity laws can be used to predict pump curves for different speeds and impeller diameters

| Speed | Diameter |
|---|---|
| $\left(\frac{Q_1}{Q_2}\right) = \left(\frac{N_1}{N_2}\right)^1$ | $\left(\frac{Q_1}{Q_2}\right) = \left(\frac{D_1}{D_2}\right)^1$ |
| $\left(\frac{H_1}{H_2}\right) = \left(\frac{N_1}{N_2}\right)^2$ | $\left(\frac{H_1}{H_2}\right) = \left(\frac{D_1}{D_2}\right)^2$ |
| $\left(\frac{P_1}{P_2}\right) = \left(\frac{N_1}{N_2}\right)^3$ | $\left(\frac{P_1}{P_2}\right) = \left(\frac{D_1}{D_2}\right)^3$ |

Q = flow rate H = head P = power N = speed D = diameter

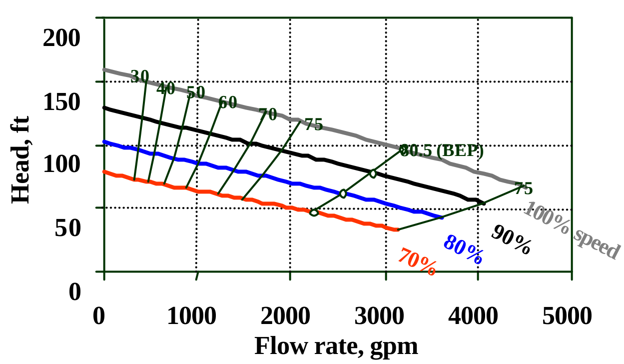
Isoefficiency lines are frequently overlaid onto head-capacity curves for multiple impeller diameters



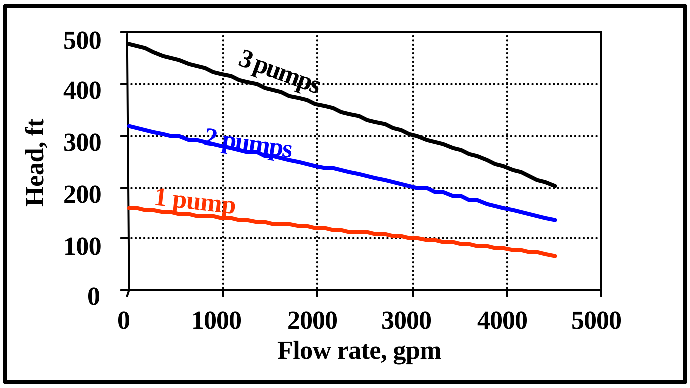





Isoefficiency lines for different shaft speeds

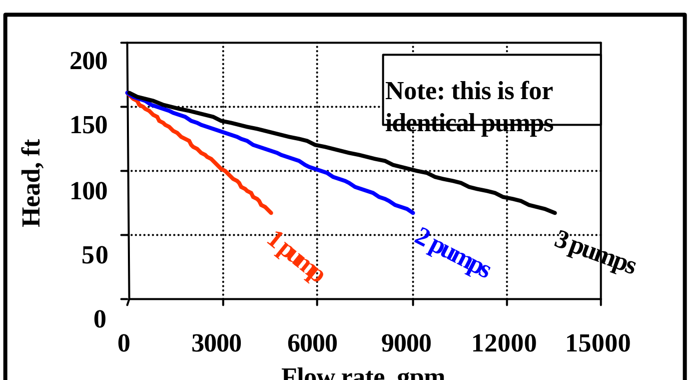


Identical pumps in series; add head at a given flow rate to estimate overall performance

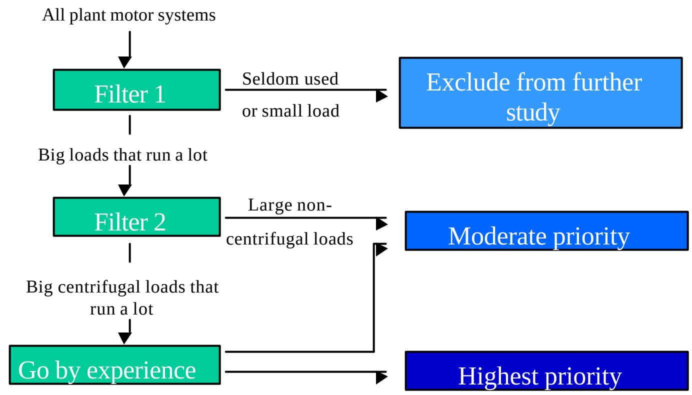





Parallel pumps can help adapt to changing system requirements <u>and</u> provide redundancy



## Select the VITAL FEW and ignore the TRIVIAL MANY



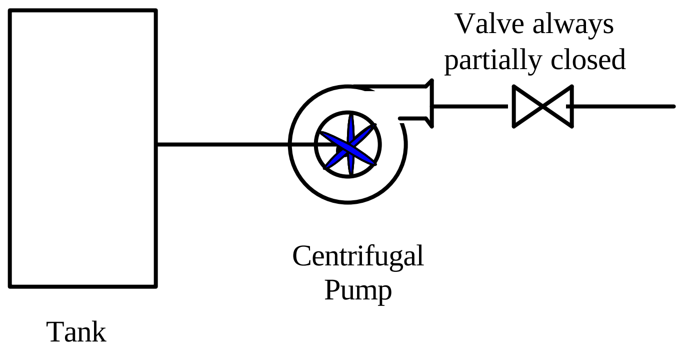





## Symptoms that indicate potential opportunity

| **Symptom** | **Likely Reason** | **Best Solutions** |
|---|---|---|
| Throttle valve-controlled systems | Oversized pump | Trim Impeller, Smaller Impeller, ASD |
| Bypass line (partially or completely) open | Oversized pump | Trim Impeller, Smaller Impeller, ASD |
| Multiple parallel pump system with the same number of pumps always operating | Pump use not monitored or controlled | Install controls |
| Constant pump operation in a batch environment | Wrong system design | On-off controls |
| Frequent batch operation in a continuous process | Wrong system design | Match pump capacity with system requirement |
| Presence of cavitation noise (at pump or elsewhere in the process) | Various | Depends on cause |
| High maintenance cost (seals, bearings). Talk to operations personnel | Pump operated far away from B.E.P. | Match pump capacity with system requirement |

# Throttle valve-controlled system

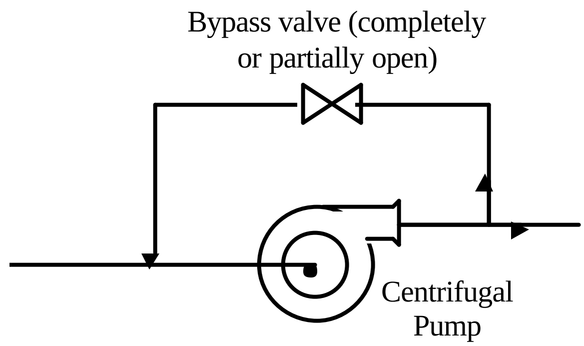





# Corrections for oversized pumps include:

- Replace the impeller of the existing pump with a smaller impeller
- Trim the outside diameter of the existing impeller
- Use an adjustable speed drive (ASD) to drive the pump

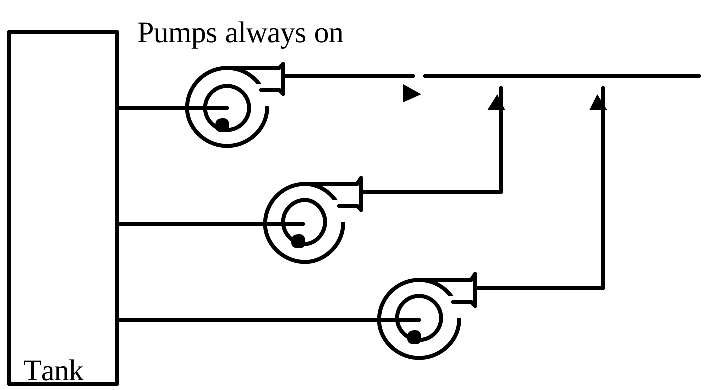
# Bypass (recirculation) line partially or completely open



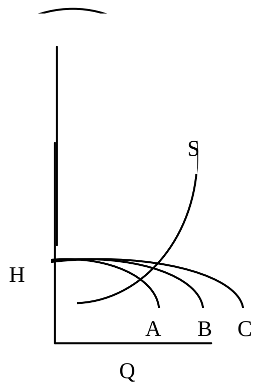





# Multiple parallel pump system with same number of pumps always operating



# Three pumps in parallel

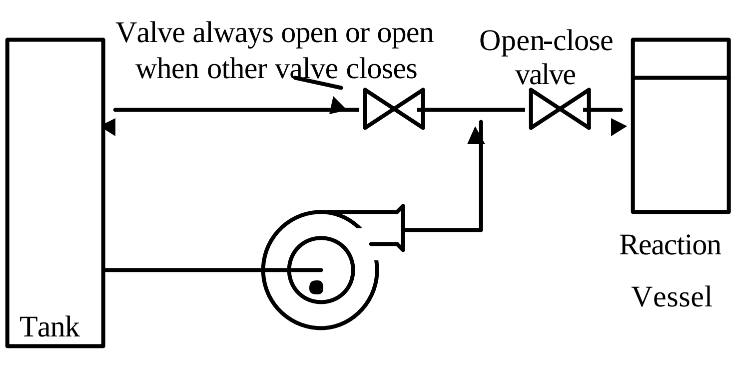



Take a good look at the diagram and you will see that the third pump (C) is intersecting the system curve at just about the same point as the second pump (B).

All of this means that the capacity of three pumps running will not be much greater than that of two pumps running.



# Constant pump operation in a batch environment



# Frequent cycle batch operation in a continuous process